Severe Plastic Deformation by Twist Extrusion

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In this work we describe and analyze a new method for reaching the severe plastic deformations that is based on the direct extrusion of a bulk through a twist channel, and thus it is called "twist extrusion" (TE). The idea of this method and some first experimental results were published in [1]. A new approach to the investigation of the grain fragmentation at SPD has been proposed and discussed. The fragmentation of grains is numerically simulated using the original Cellular Model described below.

Theoretical investigation showed that during TE the deformation is localized in the incoming and outgoing areas where the material is 'twisted' and 'untwisted'. It is shown that the maximum equivalent strain at one pass is up to 1.5, minimum in the center of the billet is about 0.5.

It should be noted that TE may engage either right-hand or left-hand twist direction. Variation of the twist direction allows additional control over the deformation pass scheme. Consecutive use of the right-hand and left-hand twist directions allows doubling the monotonous pass length. Here, the right-hand die twists the metal clockwise and then counter-clockwise immediately followed again be the left-hand die counter-clockwise twist and then clockwise twist.

Severe plastic deformation processes, in particular TE, still need an explanation of the grain refinement mechanisms. An attempt to model the grain fragmentation during the SPD of polycrystalline materials was done through the computer simulation based on the cellular automata apparatus. Polycrystalline representative volume was modeled as a population of interconnected units which, in turn, could consist of lower scale level units. Simple units not having an internal structure were deformed by sliding along the various allowed sliding systems. For consideration of stress distribution within the limits of components, the approach of self-consistent field was used. Rotation of units and moment stresses connected with it were taken into account.

Within the framework of the Cellular Model, the following grain refinement criterion is proposed. As the moment stresses on a grain reach the critical value, this grain is fractured on the fragments arbitrary oriented within a certain range of allowed angles.

It is shown that due to the grain refinement the level of internal stresses is periodically relaxed in all parts of the billet. The obtained dependence of the average grain size of the strain shows again the periodic character of the grain refinement with the periodic relaxation of the internal stresses due to this refinement.

TE allows obtaining a fine-grained structure with desirable mechanical properties comparable to those obtained by other severe plastic deformation methods. Furthermore, TE extends the capabilities of other severe plastic deformation schemes in controlling the material structure and the nomenclature of the resulting products. In particular, using certain TE schemes it might be possible to obtain products with inner holes as well as elongated profiles such as wires. In order to avoid the anisotropy of properties it is advised to combine TE with ECAP and traditional metal forming methods (e.g. rolling, drawing).

Existing TE installation allows deforming of the work piece with cross-section about 30mm and length about 100 mm. Equivalent strain during one pass is about 1. Temperature of the die may be varying between -170°C and +500°C. The additional hydrostatic pressure up to 1GPa may be applied in the deformation zone.